

INCORPORATING BIO-ENERGY PRODUCTION INTO A FOREST ZONING ALLOCATION SCENARIO FOR CROWN LAND IN NEW BRUNSWICK

By

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INTRODUCTION

In New Brunswick and elsewhere, there are global trends towards more sustainable forest management paradigms and production methods (Bengston and Xu 1995, Robson *et al.* 2000, Tarrant *et al.* 2003) that promote conservation of natural resources and reduction of greenhouse gas (GHG) emissions. There is also an increasing public recognition of the importance of non-timber forest and environmental values such as biodiversity integrity, water quality, wilderness (Boylard *et al.* 2004) or even GHG emission. This fundamental change in the public's values from predominantly economic ones to a greater emphasis on non-timber and environmental values has necessitated a change in forest management paradigms (Bengston and Xu 1995, Robson *et al.* 2000, Tarrant *et al.* 2003).

Forest managers have been using an integrated resources management approach (IRM) for many years. This approach attempts to consider multiple uses for each hectare of land as a forest management strategy to respond to public acknowledgment of the importance of management (Zhang 2003). However, after decades of practice, IRM seems merely a symbolic commitment which constrains timber production and does not satisfy the forest industry or the general public (Rayner 1998). According to Binkley (1997) and Zhang (2003), the IRM approach has failed and is inefficient both economically and ecologically.

In contrast to the IRM approach, the idea of forest zoning for priority use has become popular in recent years (Binkley 1997, Rayner 1998, Sahajananthan *et al.* 1998, Taylor 1999, Messier and Kneeshaw 1999, Krcmar *et al.* 2003, Montigny and MacLean 2006). The idea is based on the relative advantages of defining areas as having a 'priority use', which is allowed to take precedence over other uses in case of conflict (Zhang 2003).

Seymour and Hunter (1992) proposed a forest zoning approach in which three different land uses are suggested. In this approach, which is called the TRIAD, the forest area is allocated into zones termed intensive, extensive and reserve. Within these zones, timber production emphasis ranges respectively from: the main objective, to a mix with non-timber objectives, to being completely constrained (Ward 2006).

To date, the TRIAD approach has been tested by many researchers as an interesting alternative which seeks to provide the full range of society's values (Sahajananthan *et al.* 1998, Taylor 1999, Messier and Kneeshaw 1999, Krcmar *et al.* 2003, Montigny and MacLean 2006). However, three zones is not the only way to apply forest zoning and manage forests. Messier and Kneeshaw (1999) suggested a similar zoning approach using four zones (QUAD) rather than three. They advocated dividing the intensive management zone into two zones using traditional intensive silvicultural techniques (plantation, thinning, clearcutting, etc.) on one part and super-intensive management on a smaller area, using highly productive exotic and hybrid species. Messier and Kneeshaw (1999) demonstrated that fast growing plantations offer a means of achieving timber production targets while promoting the protection and conservation of our forest heritage. However, these researchers have not tried to evaluate biomass and bio-energy production in addition to fibre production from the super-intensive zone.

In New Brunswick, alternative energy in the form of renewable biomass (forest products), and carbon sequestered in trees could be used to reduce New Brunswick's dependence on fossil fuels and net emissions of greenhouse gas (NBDE 2007). The province has an opportunity with its vast bio-resources to take advantage of expected national and international biotechnology markets by selling biomass, bio-energy and carbon credits.

Biomass and bio-energy could thus be appropriate end uses for wood when prices for other wood products such as sawlogs and pulpwood are decreasing. These new products could also be used to offset domestic, commercial, and industrial energy, and to revitalize rural economies and create new industries (Hillring 2006).

Currently, the industry and the government of NB are looking for opportunities to undertake demonstration projects that showcase the benefits of renewable and alternative technologies and jumpstart the markets to manufacture, sell, and maintain renewable and alternative technologies. In 2005, the government of NB commissioned a Provincial Task Force to evaluate forest policies and develop practical forest management alternatives for Crown land. These alternatives must promote a healthy wood supply, conservation of natural resources, and the use of renewable sources of energy – yet retain characteristics of the Acadian forest (NBDNR 2006b). In this present study, the feasibility of bio-energy production from wood under forest zoning allocation scenarios for all Crown land in NB will be evaluated.

RESEARCH OBJECTIVES

A combined timber supply model for all Crown forest licenses in New Brunswick, built by the Provincial Crown Forest Task Force (NBDNR 2006b), will be adapted for use in this study. The objectives of this research are: (1) to evaluate biomass and bio-energy production potential; and (2) to analyze the effects of various forest zoning allocation scenarios on a variety of variables simulated over an 80-year time period for all Crown forests in NB.

METHODOLOGY

Study Area

The study area will be the entire Crown land of New Brunswick. New Brunswick is characterized by the Acadian forest region, and wedged between boreal coniferous forest to the north and deciduous forest to the south. This gives a large diversity of vegetation, including 39 species of native trees. New Brunswick Crown land occupies a total area of 5.3 million hectares (51% of the entire province), of which 2 million ha are submerged by water and 3.3 million ha are commonly called ‘upland’ and characterized by various activities for sustainable development (NBDNR 2006a).

The forest industry harvests about 4.7 million cubic metres per year of wood from the public forest. This includes 3.2 million cubic metres of softwood and 1.5 million cubic metres of hardwood (NBDNR 2006a).

More than 14 000 hectares are planted per year. Pre-commercial thinning is carried out on nearly 24 000 hectares per year. Federally approved herbicide is applied, from the air, to more than 12 000 hectares and, from the ground, to about 300 hectares per year (NBDNR 2006a).

Over 800 Deer Wintering Areas (DWA) covering about 280 000 hectares of forest are managed for white-tailed deer (*Odocoileus virginianus* Boddaert). Approximately 260 000 hectares are managed for wildlife that need large areas of old softwood forest. Over 190 000 hectares are managed for wildlife needing older pine, hardwood and mixedwood forest. Also, 400 000 hectares of buffer zones exist around lakes, rivers, streams and wetlands to protect water quality and fish habitat (NBDNR 2006a).

New Brunswick has 10 large and 20 small protected areas covering more than 150 000 hectares (4.5%) of forested Crown land. The public forest is used for many other purposes including: 1 100 hectares for campsite leases, 8 300 hectares for maple sugary leases and 6 200 hectares for blueberry leases. There are also more than 4 500 km of hiking, snowmobile and ATV trails on public land (NBDNR 2006a).

Merchantable Volume and Biomass Development Forecasts

The Provincial Task Force has used the latest version of the *STAMAN* stand table projection model and the *NBGYU database* to construct stand development forecasts to be used in the forest-level Woodstock model. However, this model has been primarily built for forecasting merchantable volume growth and yield by products and species (Norfolk 2006), but not for biomass growth and yield forecasts. Therefore, a new biomass extension will be developed for *STAMAN 5.5.2* and the *NBGYU database* as a tool to quantify above-ground live biomass stand yields by species and tree components (foliage, branch, stemwood and merchantable products).

Development of the *STAMAN* biomass extension will comprise three stages involving: 1) review of tree allometry literature, 2) selection of representative biomass equations for NB stand types (natural, managed) and species, and 3) programming *STAMAN* to apply equations during stand growth/yield forecast development. Equation selection will be based on 1) study location (Acadian or similar forest sites), 2) accuracy (size and quality of data source), and 3) equation form (independent variables limited to species and DBH). The stand-level biomass forecasts produced by this new extension of *STAMAN* will be incorporated into the Task Force timber supply model and used to evaluate Crown land planning for alternative bio-energy production strategies for different forest-level management scenarios. This new component will also allow evaluation of the current biomass inventory and its projection over time.

Wood energy conversion technologies

There exists a wide range of technologies for converting biomass to other forms of energy. Most biomass energy technologies can be classified according to the following processes: direct combustion, thermo-chemical conversion and bio-chemical conversion (RWEDP 2007).

Direct combustion will be the biomass energy technology used for this study. This type of technology deals mainly with primary fuels e.g. the form in which it is available in nature or after some form of processing (drying, sizing, briquetting). Primary fuels subject to direct combustion are used for Heat generation, Electricity generation, and Co-generation (RWEDP 2007).

The energy content of wood from various tree species will be calculated using their specific calorific values (e.g. kJ/kg). Most of those values will come from the *Phyllis* database of the Energy research Center of the Netherlands (ECN 2007), and from other sources as needed (Klass 1998, Richardson *et al.* 2002).

Forest Zoning

This research will use the QUAD form of land use zoning, as proposed by Messier and Kneeshaw (1999) and followed by Messier *et al.* (2003). In this approach, the forest area is allocated into zones termed super-intensive, intensive, extensive, and reserve.

Different methods will be used to identify the zones for this forest zoning approach. Knowing that location and preservation of protected areas is one of the main goals of forest zoning, the reserve network will be identified first. Identification of remaining zones will be prioritized by a descending order of money investment, and will begin with the super-intensive zone, followed by the intensive zone, and the extensive zone respectively. However, key to identifying these zones is an understanding of objectives for zones into which area is allocated and the actions that can be implemented in these zones (Montigny and MacLean 2006).

Reserve Network

The method described by Montigny and MacLean (2005) will be used to select the area allocated to this type of zone. This method will be applied to each License, and will use *ArcGis Spatial Analyst* with the heterogeneity method to select forest reserves. More

specifically, candidate areas will be selected with maximum diversity of 1) forest species composition, 2) maturity classes, 3) soil types, and 4) elevation classes to incorporate the greatest amount of forest features in the smallest area. In addition, the total area of plantations and treated stands that are currently in candidate areas will also be used as an indicator of suitability for reserve (the minimum the better). Different targets will be used with this method such as 6%, 9%, 12% and 15%, which represent approximately an increase of 3% of the current reserve network each time. Areas proposed by this method will be added to the current reserve network to reach the targets previously defined. Each reserve will be identified in the GIS database with a unique identifier and will allow reserves to be spatially constrained in the Task-Force timber supply model.

Reserves are managed to provide ecological benchmarks and to represent forest conditions unaffected by timber management practices. Therefore, no timber will be extracted from reserves and natural ecological processes will be allowed to occur (Montigny and MacLean 2006).

Super-Intensive and Intensive Management Zones

The method described by Norfolk and Erdle (2005) will be applied to each License to select the area allocated to these types of management. This approach will use *ArcGis Spatial Analyst* with a quantitative process for ranking candidate areas based on their suitability for super-intensive and intensive management, involving: (1) defining candidate areas, (2) specifying indicators for economic, ecological, and social criteria of suitability and scoring each candidate relative to those indicators, and (3) ranking candidates using a composite index that factors in all suitability indicators (Norfolk and Erdle 2005). Two analyses will be done to identify the total area needed for a combination of super-intensive (25% of combined total) and intensive zones among scenarios. Once the analyses are done, each zone will be identified in the GIS database with a unique identifier and will allow these zones to be spatially constrained in the Task Force timber supply model.

Following the reserve network identification, the second analysis will identify the super-intensive management zones needed for each scenario. The different targets to be used with this method are 1%, 2%, 3%, 4%, 5%, 7%, 9%, and 11% of NB Crown land. In this research, the super-intensive management zones will be similar to intensive agriculture, where stands are managed solely for timber, biomass, and bio-energy production. It will be characterized by clearcutting, followed by intensive site preparation, plantation of uniform single-species, genetically selected trees, followed by strict vegetation control, fertilization and thinning. Exotic species such as hybrid poplar (*Populus hybrids* sp.) (less than 20 to 30 year rotation) and willow (*Salix* sp.) (less than 3 to 5 year rotation) will be considered. Candidate area selection for this type of management will be carried out with the following indicators: 1) slope percentage, 2) transport distance from the center point of candidate areas to the center point of NB communities (distances weighted by community energy supply and demand) (Statistics Canada 2007), 3) road density (km of suitable road per km² of forest area), 4) ecosites 5-7 (Zelazny 1998), 5) proximity of protected areas from each candidate area (the farther the better), and 6) the total area of plantations and thinned stands in each candidate area.

The third analysis will identify the intensive management zones needed for each scenario. The different targets to be used with this method are 3%, 6%, 9%, 12%, 15%, 21%, 27%, and 33%. In this zone, the land will be managed primarily for the production of timber products, biomass and bio-energy. Traditional silvicultural techniques such as plantation, precommercial thinning, commercial thinning, clearcutting, shelterwood harvesting, strip and group selection harvesting, single-tree selection harvesting, and salvage harvesting (fire or insect damaged) will be considered. Planted species will include black spruce (*Picea mariana* [Mill.] B.S.P.), white spruce (*Picea glauca* [Moench] Voss), red spruce (*Picea rubens* Sarg.), and jack pine (*Pinus banksiana* Lamb.). The candidate area selection for this type of

management will be carried out with the following indicators: 1) site index values (height at age 50 years) for black spruce (data from Norfolk 2003), 2) transport distance from the center point of candidate areas to the center point of NB communities (distances weighted by community mills demand) (NBDNR 2006c), 3) road density (km of suitable road per km² of forest area), 4) ecosites 1-2-3-4 (Zelazny 1998), 5) proximity of protected areas from each candidate area, and 6) the total area of plantations and treated stands.

Extensive Managements Zones

The remaining area will be allocated to the extensive management zone, and will also be identified in the GIS database with a unique identifier. This identifier will allow the extensive zones to be spatially constrained in the Task Force timber supply model.

In this zone, the land will be managed less intensively for timber, biomass, and bio-energy production in order to make allowances for non-timber values such as terrestrial wildlife habitat, aquatic habitat and water quality. Traditional silvicultural techniques such as clearcutting, shelterwood harvesting, strip and group selection harvesting, single-tree selection harvesting, and salvage harvesting (fire or insect damaged) will be considered. Biomass harvesting will only be considered on ecosites 5 and 7 (optimal sites) (Zelazny 1998) in order to have a lower impact on site quality.

Criteria and Indicators

Several indicators have already been selected by the Provincial Task Force to enable scenario evaluation with respect to important timber and non-timber values. This research will focus on development of biomass and bio-energy indicators, not considered by the Provincial Task Force. The contribution to GDP of biomass and bio-energy production, and harvest volume by species and products, will be evaluated. Effects of scenarios on timber, biomass and bio-energy production, and areas of various stand types, habitat and vegetation communities, and no harvest zones by ELC unit (Zelazny 1998), will be quantified as well.

Scenario Modeling and Constraints

A combined model for all Crown forest licenses in New Brunswick, built by the Provincial Task Force, will be used as a basic structure and will be adapted in order to reach the objectives of this research. The software used for management strategy formulation, forest development forecasts, and calculation of indicators will be the Woodstock forest modeling system (Remsoft[®] Inc. 2006). The software will be used to forecast forest development and calculate indicators for an 80-year time period (16 periods @ 5-years/period).

Linear programming formulation will be generated to solve an objective function based upon a single forest-level objective while being subject to various constraints that must be met to reach an optimal solution. More specifically, maximization of bio-energy produced from the super-intensive, intensive, and extensive zones will be used as an objective function in the linear model while being subject to various constraints that follow the statements in the NB Vision document (NBDNR 2005) and the Self Sufficiency Task Force Report (GNB 2007).

Model Constraints

A non-declining (NDY) softwood and hardwood yields (GNB 2007), non-declining total growing stock will be included. A constraint to set the Provincial Spruce, Fir, Jack Pine AAC greater or equal to 3.2 million cubic meters (softwood level established in 2002), a constraint to set the Provincial hardwood AAC greater or equal to 1.5 million cubic meters (hardwood level established in 2002), a constraint to maintain at least 12% of the total area in each vegetation community as defined in the 1982 provincial inventory adjusted for human disturbance, and a constraint to meet the NB objectives for the six old-forest wildlife habitats (OHWH, OTHH, OPIH, OMWH, OSFH and OFH) will be applied (NBDNR 2005). The total area for DWA in any 5-year period of the planning horizon will be constrained as well to make sure that it cannot be reduced by more than 15% in any one 5-year period (NBDNR

2005). Black spruce, white spruce, red spruce, and jack pine plantations will only be allowed to occur in the intensive zone. Hybrid poplar and willow plantations will only be allowed to occur on the super-intensive zone. Precommercial thinning and commercial thinning will only be allowed to occur on the super-intensive and intensive zones. Shelterwood harvesting, strip and group selection harvesting, single-tree selection harvesting, and salvage harvesting will only be allowed to occur on the intensive and extensive zones. In addition, a constraint in order to cut the oldest stand first, a no-harvest constraint for the reserve network, and a timber and biomass production constraint that gives the priority to the super-intensive management zone will also be applied to the model. Finally, a constraint to set biomass harvesting only on ecosites 5-7 for the extensive zone will be applied as well.

Analysis of Land Allocation Scenarios

This research will evaluate 40 scenarios with the Provincial Task Force timber supply model and the previously identified zones (GIS database with unique identifiers). For each scenario, varying areas will be allocated to one of 4 forest management intensity zones: super-intensive, intensive, extensive, and reserve. Scenarios will allocate between 4% and 44% of Crown land to a combination of super-intensive and intensive zones. Specifically, the scenarios to be considered are 4%, 8%, 12%, 16%, 20%, 28%, 36%, and 44% allocated to these types of management. The super-intensive zone will represent 25% of this combination. The area allocated to reserve will vary from 4.5% (current reserve network on forested Crown land) to 15% at 3% intervals (4.5%, 6%, 9%, 12%, and 15%) and will remain constant among scenarios. The remaining area will be allocated to the extensive zone.

In general, existing stands in areas that have been identified as suitable for a specific management zone will be managed following an optimized solution. It will be regenerated and managed according to specific zone objectives and constraints.

In order to make comparison, the Task Force current forest policy scenario (business as usual) will be used as the base scenario. Some other scenarios with only a variation of area allocated to super-intensives zone (1 to 11% of Crown land) with the current management regime in NB will be run as well.

Analysis and Evaluation of Results

Analysis of results will allow answering several questions to assist the Government of New Brunswick in policy making, and forest managers at the forest management planning and decision making stages. These questions are mainly: What are the effects of alternative zoning scenarios on biomass and bio-energy production, and timber and non-timber values? What trade-offs exist between multiple values? What compatibilities exist between multiple values? What are the effects of a given zoning allocation on a given indicator over time? What potential exists for increasing area allocated to reserve zones? What strategies exist for allocation scenarios, and what are the trade-offs? What bio-energy production might be possible from the super-intensive poplar/willow energy plantations?, etc.

In general, scenario analysis will provide an effective framework to assist in land-use decisions by identifying trade-offs between forest values and by helping to elucidate trends in biomass, bio-energy, and forest dynamics. The results from scenario analysis will also provide numbers for public debate in New Brunswick and thus help to define new forest, biomass, and bio-energy policies for the province as recommended in the Self Sufficiency Task Force Report (GNB 2007).

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